# Geophysical characterization of pre-Holocene limestone bedrock underlying the Biscayne National Park Reef Tract, Florida

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## Abstract

Shallow seismic investigations of the Pleistocene bedrock beneath the northern Florida Reef tract revealed the presence of a deep channel that is presently infilled with up to18 m of unconsolidated sediments. The channel is located 3 km east of the present shoreline at Elliot Key and cuts across the shelf towards an indented valley-like feature between the offshore bank margin reefs of Long Reef and Triumph Reef. The orientation, slope, and morphology of the channel suggest a fluvial origin, but other explanations such as a collapsed cave system cannot be ruled out. The channel has influenced patch reef formation by limiting reef growth to the elevated margins of the channel and not the channel axis, which is presently covered by sand. It is likely that other similar channels exist, but they can only be identified with further high resolution surveys. The existence of a more extensive channel network in the northern Florida shelf may suggest that fluvial processes during the last glacial were more active than previously thought.

## INTRODUCTION

Surface topography of the Pleistocene bedrock underlying Holocene sediments of the Florida Reef Tract has long been interpreted as primarily depositional in origin with only minor alteration by sub-aerial erosion (Enos, 1977; Lidz and Shinn, 1991). Pleistocene relief features typically run parallel to the modern reef axis and are composed of reef corals (Hoffmeister and Multer, 1968; Shinn et al., 1977). Hoffmeister and Multer (1968) initially suggested that shelf-margin highs were erosional remnants of a once more extensive barrier, but Enos (1977) argued that a depositional origin was more likely based on the shape and orientation of the buttresses.

Incised channels are fairly common in mixed siliciclastic shelf areas such as Belize (Purdy, 1974; Esker et al., 1996) and Australia (Johnson et al., 1982). These channels are often interpreted as erosional in origin when oriented cross shelf. Incised channels are less common in purely carbonate shelf settings. Small channels have been found in south Florida Pleistocene bedrock. Turmel and Swanson (1976) found a 2-3 m deep channel north of Rodriguez Key. Channels between the Keys, such as Caesar's Creek and Angelfish Creek, extend 2-5 m below the surrounding bedrock. In general, these channels have been interpreted as original tidal channels that were located between topographically high reefs during the last interglacial (Warzeski, 1976).

Topographic features in the Key Largo limestone interpreted to have a karst or dissolution origin are mainly isolated small depressions. Enos (1977) identified numerous depressions that extend 2-8 m below the surrounding rock floor surface, which were interpreted as dolines or sinkholes formed by ground-water solution. He noted concentrations of these depressions in certain areas and an orientation to the northeast. Lidz et al. (1997) identified a single, large infilled sinkhole east of Key Largo that measured approximately 50 m wide and over 55 m deep. The sinkhole was interpreted to have been produced by ground water solution and ceiling collapse.

This paper briefly describes topographical features of pre-Holocene limestone bedrock underlying the Biscayne National Park (BNP) reef tract. Biscayne National Park is located on the southeast tip of the Florida Peninsula and encompasses an area that includes the shallow coastal areas of Biscayne Bay and the offshore reef tract. The outer shelf extends from a series of mid-shelf Pleistocene islands, the largest of which is Elliot Key, out to the shelf margin reefs of Pacific, Ajax, Long, and Triumph (Figure 1). Modern shelf communities consist of extensive seagrass beds, sediment banks, sand, and reefs, some of which can reach sea level.

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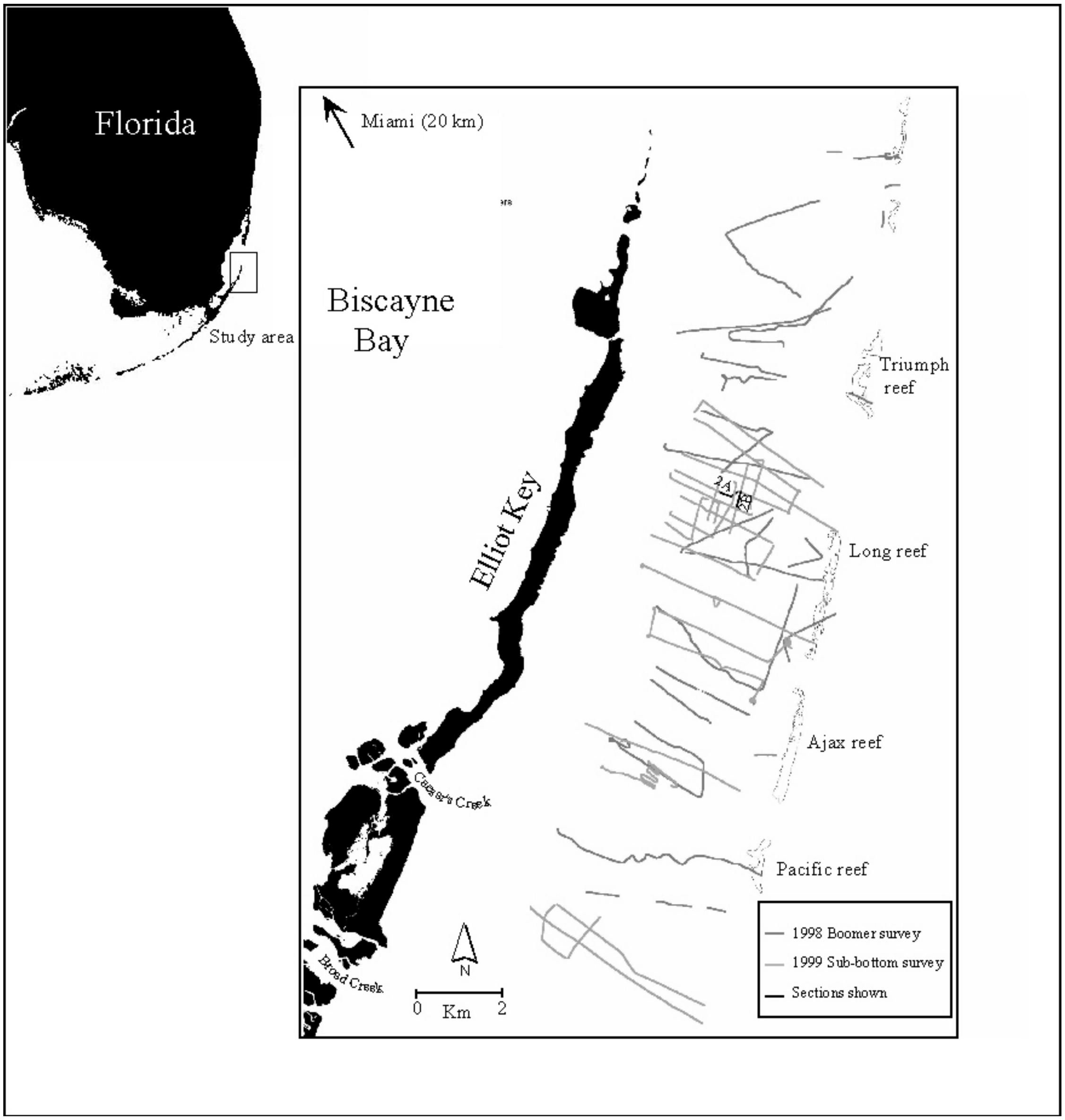


Figure 1 : Location map of south Florida showing seismic data sets from 1998 and 1999 used in this study and position of section profiles shown in figure 2.

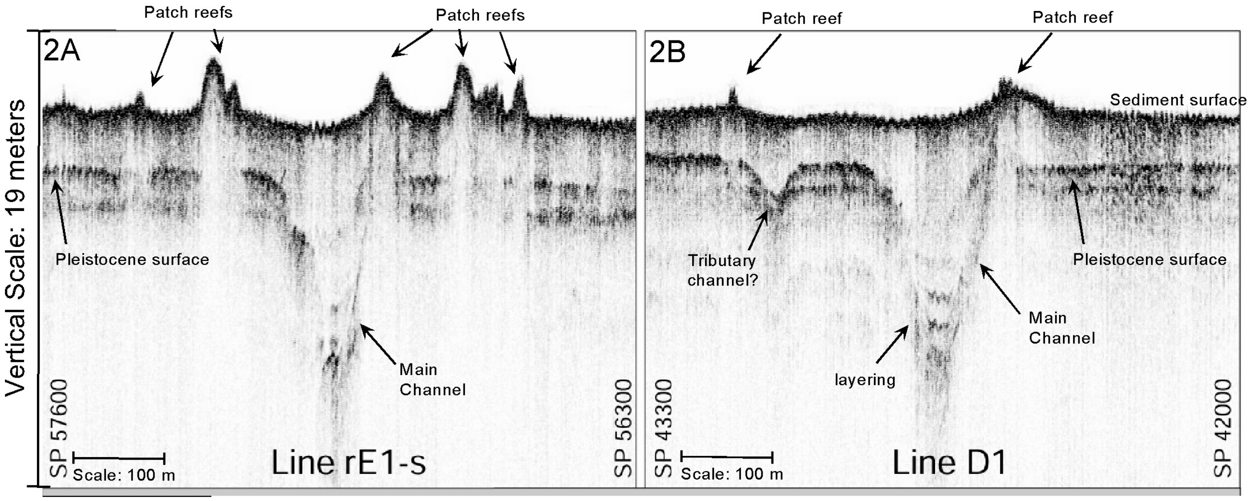


Figure 2: Sub-bottom profiles across two sections of the channel and control on patch reef growth.

The abundance of patch reefs is particularly high in this section of the Florida Reef tract (Marszalek et al., 1977; Shinn et al., 1989). Carbonate sediments deposited during the Holocene transgression cover most of the Pleistocene surface to a thickness up to 14 m (Enos, 1977).

## METHODS

Seismic reflection profiles were recorded during field surveys in Biscayne National Park in September, 1998 and November, 1999. For the first survey, a Geoacoustic boomer source and 4-element streamer were mounted on a shallow draft boat equipped with a 220 volt generator. Lines were shot at 200 joules with a shot interval of 300 ms. These settings allowed features greater than 50 cm to be resolved and penetration to the Holocene/Pleistocene interface, except over well cemented hardbottoms and reefs. A total of 80 km of lines were shot with a spacing between 3 and 5 km covering most of the study area (Figure 1). Raw data were recorded in SEG-Y format and later resampled and post-processed with bandpass (300-2500 Hz) filter and deconvolution filter to further enhance features.

The second survey utilized a sub-bottom profiler (Edgetech model SB-0512) set with a FM frequency pulse between 0.5 and 8 kHz. Resolution of sedimentary and bedrock features was typically 10 cm or better. The sharp impedance contrast between unconsolidated sediments and Pleistocene bedrock was clearly visible but could rarely be seen beneath well-cemented patch reefs and bank-margin reefs. Surveys were focused on areas with the greatest topographical relief features based on the boomer survey. A total of 73 km of lines were shot centered near Elliot Key with line spacing generally less than <1 km (Figure 1). The close spacing of lines was necessary to distinguish a single depression indicative of a doline or sinkhole from networks of connected depressions indicative of a channel.

Positioning for both surveys was achieved using a Trimble GPS receiver with real-time differential correction to +- 5m. The two datasets were merged and the Pleistocene/Holocene interface identified in travel time units. Travel times were converted to approximate depths using a mean acoustic velocity of 1500 m/s. The offset produced by changing water depth, waves, and the depth at which the instruments were being towed was determined by comparing intersections between seismic shot points and NOAA bathymetry point data. Calculated Pleistocene depths were verified by hand probing and overall accuracy was estimated at +/- 0.5m.

## SUMMARY

Surface topography of the Pleistocene surface beneath the BNP reef tract is dominated by small-scale depressions of various sizes with very few positive relief features. Depressions are concentrated on the shelf between -8 and -14 m below mean sea level. They vary from small V-shaped depressions less than 10 m across and 1 m deep, to large U-shaped features more than 200 m across and 10 m deep. Larger scale surveys by Enos (1977) also found that large depressions were more concentrated in Biscayne National Park in comparison to the rest of the Florida Reef Tract. Nearly all depressions are infilled with sediments to the level of the seafloor (Figure 2). Closely spaced reflection profiles around one of the larger depressions detected during the first boomer survey revealed adjacent depressions of similar width and depth oriented in an east-west cross shelf direction. Correlation between depressions suggests they are connected as part of a channel system rather than a network of isolated sink holes. Examination of 1:48,000 color aerial photographs shows traces of the channel expressed as a sand gap that winds between modern patch reefs.

The channel begins near the seaward edge of present day Hawk Channel about 3 km from Elliot Key and winds for at least 3.6 km across the shelf towards an indented valley-like feature between the offshore bank margin reefs of Long Reef and Triumph Reef (Figure 3). The average depth of the main channel is 10 m below the surrounding Pleistocene bedrock and about 22 m below present day sea level. A gradual seaward gradient of 1:1000 in the channel floor is similar to the off-shelf gradient in the adjacent rock floor. Midway up the main channel axis a distinct split occurs into two channels of similar depth and width which diverge to the northeast and southeast, respectively (Figure 3). The two channels appear to end abruptly near Hawk Channel in a near vertical step of nearly 8 meters. It is possible that the channel continues beyond what we have traced, but no deep (>8 m) depressions were identified further inland. Shallow (<2 m deep) depressions detected north and south from of where the main channel ends may be feeder tributaries, but more profiling is necessary to verify a connection to the main channel. The morphology of channel is similar in appearance to modern tidal channels such as Caesar's Creek and the Safety Valves but considerably deeper.

The origin of the channel is somewhat enigmatic and several possibilities will be discussed. A primary depositional origin is not likely since sub-aerial exposure would have rounded and flattened the original channel margins. It is possible that the channel represents a collapsed underground cave system formed by groundwater solution during the last glacial. Groundwater sources would be numerous with Biscayne Bay and the adjacent mainland providing a potential drainage basin. A collapsed cave would result in large limestone blocks infilling the base of the channel and these were not observed in the profiles. Furthermore, the gradual seaward gradient of the channel and winding, branching morphology suggest a fluvial origin, although a sub-surface karst origin can not be ruled out.

The main argument against a fluvial explanation is that the high porosity of the Miami Limestone, lack of tectonic faulting, and flat topography of South Florida all favor slow diffuse flow rather than the channelized flow necessary for fluvial cutting. Development of surface flow in porous limestone requires either cemented calcrete caps or impermeable soil to be present (Ford and Williams, 1989). Laminated calcrete crusts are found capping most Pleistocene sequences in south Florida (Multer and Hoffmeister, 1968). Since these crusts require prolonged periods of sub-aerial exposure to form, it is likely that channelized flow was not developed until the later part of last glacial period.

A fluvial explanation would still require a mechanisms to incise through cemented limestone. It is unlikely that dissolution from meteoric water alone could remove enough limestone to account for the channel. A more likely explanation is that some of the down cutting was caused by mechanical erosion from either small amounts of siliciclastic sand or some other abrasive. An obvious source for such an abrasive sand is not evident at this time. Modern analogues of large coastal rivers in south Florida include the Miami River and Oleta River which drain the eastern Everglades. The fact that the channels of these rivers do cut as deep into the bedrock may simply result from the less pronounced slope in bedrock compared to the outer shelf.

The outer Florida shelf was flooded by rising sea-level approximately 8 kyr ago (Lidz and Shinn, 1991). Patch reef growth is estimated to have started soon after the platform was flooded. The channel influenced the development of patch reefs by limiting where they could nucleate. Seismic sections (Figure 2) clearly show how patch reef growth around the channel is more limited to the margins of the channel and not in the sediment-filled center of the channel. Patch reefs are found along both sides of the channel but are most abundant on the northern bank. This is in agreement with previous studies (Purdy, 1974; Shinn et al.. 1977; Halley et al. 1977) that suggest that reefs cannot form on preexisting topographic depressions, but are favored to grow on topographic highs or irregular surfaces. The complex shelf topography created by incised channels and numerous depressions may also play a role in explaining the astounding abundance of patch reefs in this part of the Florida reef tract.

The presence of a large incised channel in the outer Florida shelf raises the possibility that pre-Holocene fluvial processes may be more important than previously thought. It is likely that other similar channels exist, but they can only be identified with further high resolution surveys. Core drilling is needed to better understand the origin of the channel, timing of formation, and infilling history during the Holocene transgression.

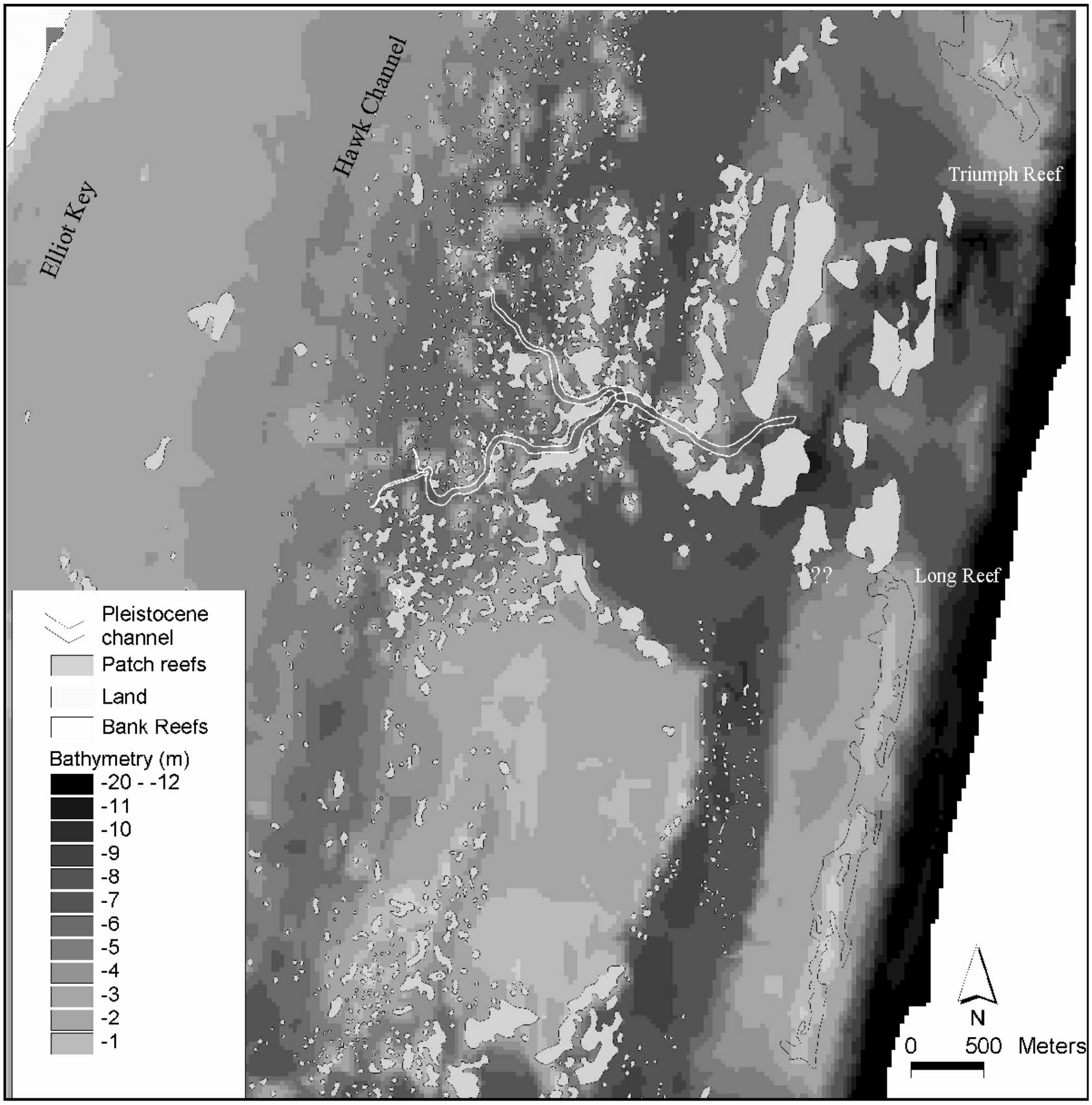


Figure 3: Map showing the location and morphology of the channel superimposed on position of mapped patch reef. Bathymetric data illustrate the location of larger shallow sediment banks and bank-margin reefs.

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